Self-study Checklist
Changing Weather Challenges and Adaptation Strategies for Northeastern U.S. Tree Fruit Growers

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for "The Climate Adaptation Fellowship: A Collaborative Curriculum Design Project"
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I) How to Use this Checklist

Making a profit growing tree fruit in the Northeast has never been easy, but could become more difficult in the coming decades as climate change progresses in the Northeast. Changes in average temperature, precipitation, and other weather variables, and in patterns or variability such as more frequent and intense temperature and precipitation extremes will affect not only orchard fruit tree health and productivity, but also management operations, marketing and other aspects of running an orchard business.

This document is a checklist of possible climate and weather-related challenges, and some opportunities that may increase over the next 30 years, with actions tree fruit growers can take to reduce risk or maximize opportunity. It is designed to be useful for growers at different scales and markets (wholesale, retail, pick-your-own, organic, IPM, etc.), but of course not every possible solution will be suitable for your situation. We chose to be inclusive so as not to exclude ideas that may be useful, even if only to a few growers.

These are suggestions to consider, and are not the only answers. Reading through the list can introduce you to some risks and adaptation strategies you may not have previously been aware of, or at least remind you about ones you already did know. The list was generated by four commercial-scale New England tree fruit growers who primarily grow apples, but who also have experience with peaches and other stone fruit. The list may not fully represent orchards in the most intensive tree fruit production areas of the Northeast U.S., (New Jersey, New York, Pennsylvania) or other states outside of New England. Likewise, this document is focused on apples, growers who specialize in stone fruit will no doubt know of weather challenges and adaptation methods not included in the list.

Eventually, the checklist could be expanded to provide many more links to key resources for the information needed to plan for and implement the adaptation strategies mentioned in the list. In this first edition, we only completed the initial stage of that phase. We hope that once this workbook reaches a larger audience, reader suggestions will provide content links to add to the resource lists.

There are trade-offs between being comprehensive and being concise. This workbook cannot aspire to be the encyclopedia of tree fruit production and remain an efficient study guide. At present, it is a first draft for further development for the idea of a usefully comprehensive list of information resources relevant to the needs of Northeastern U.S. tree fruit growers looking to prepare for expected weather changes over the next few decades.

Weather risks have always been a fact of life for orchard managers. Most of the weather risks listed in this document already occur, so methods to reduce vulnerability to weather challenges is useful today in addition to preparing for increased frequency and intensity of such events in the coming decades.

The list of adaptations includes physical changes such as adding drainage tile or irrigation. It also includes marketing, finance, and other management options. Some of the proposed solutions are beyond what individual growers can implement on their own. Cooperative Extension, Natural Resources Conservation Service (NRCS), Farm Service Agency (FSA), Risk Management Agency (RMA) and other Federal and state programs are available to help farmers. In addition, private sector service providers such as crop consultants, grower cooperatives, and financial institutions can provide assistance.

Following each of the weather impact categories, there are four review questions to consider. The term "no regrets" adaptations refers to changes that make sense even without the increased risks posed by changing weather and climate.

It may be tempting to skim over those questions and move ahead to the next section. But like any other form of exercise, the benefits from using this self-study workbook will depend on the investment you put into it. The act of responding to those questions engages you in a mental conversation. You will get more lasting value from this workbook if you take the time to seriously consider each of those questions and record your thoughts. It may help to separate Tables 1 and 2 in the section III) Adaptation from the rest of the document so that you can consolidate your responses to the review questions into the tables for later use. There are no right or wrong answers, and nobody is going to grade you.

A review of the business climate for U.S. apple growers (O'Rourke 2019), though not addressing climate change specifically, provides an apt summary of the situation:

"Growing, packing and marketing fresh apples will become more complex, and more expensive, and will involve increased risk. Only the firms that are best at identifying emerging opportunities and adapt their organizations accordingly will continue to prosper."

The section below contains text adapted from Global Food Security (2016). References in the original were excluded for clarity.

Putting thoughts into action

We learn best by doing. After reading and considering how each checklist section applies to your orchard, taking the next step to record your observations, thoughts, questions, and plans is the key to getting benefit from this workbook. Discussing those notes with your family and business partners, and finding consensus and commitment to move forward is another key step. **That three-step process** (record ideas and questions – discussion – commitment) **can help you turn Information into Decisions, Decisions into Actions, and Actions into Success.**

If changes are needed to adapt to new weather challenges, it is better to foresee the situation and act early vs. waiting until damage occurs.

Seek advice from appropriate professionals. **But remember that your first-hand experience is irreplaceable.** The more you can narrow the focus in identifying existing and potential problem(s), the more focused the you and your service providers can be in identifying solutions. While your role is unique and irreplaceable, **you are not in this alone**. Greater collaboration between growers, Extension and research staff, and other private and public sector ag support entities enhances food system management and resilience.

Include your family and business team in considerations of climate change risks and adaptations. **No one person has all the answers. Participation in identifying the problems and solutions is key to getting all of your team to be committed in carrying them out.** Recognizing the reality and scope of global climate change is daunting. Effective response requires not getting overwhelmed. This curriculum is focused on maintaining a profitable tree fruit orchard, not changing the whole world. The issues highlighted here are based on reasonable expectations for conditions that will emerge over the next 30 years, possibly much sooner, and some that are already being noticed.

Regional climate change projections do not have perfect predictive skill, and the biggest unknown is how and when societies will react to the crisis. But projections do provide useful guidance to help you plan for the future.

Everything is connected. This is especially important as the global food system becomes more integrated. Those interconnections facilitate the transmission of risk through food markets to have a variety of repercussions at multiple scales:

Climate – Weather – Production – Pricing – Markets – Profitability

The risks associated with climate change are more than simple trends in average weather. While we have significant skill in understanding how the climatic averages are changing, our ability to forecast volatile weather extremes and their potential impacts on the food system is far from sufficient. Variability in the weather and how it impacts the food system receives less attention but is critically important to producers and consumers.

An assumption that the challenge of climate change consists solely of how to adapt to gradual change in conditions, and that future weather will simply be the same as today's, but on average a few degrees warmer, would be dangerously incomplete. There is potential for the mean climate and its variability to become uncoupled. For example, rainfall totals can increase on average, but if their variability also increases, then drought risk can also increase. As the patterns and distribution of weather changes, unprecedented events become more likely.

End of text adapted from Global Security, 2016

II) Weather challenges to tree fruit production and Adaptations checklist

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1. High volume rain events.

The amount of rain in the most intense events has increase 55% in the Northeast In recent decades. The number of rain events per year in Maine with over 2 inches within 24 hours doubled from 2000-2009 to 2010-2017. The frequency of 2-inch rain events in the Northeastern U.S. tree fruit growing areas is expected to increase 25% to 100% between 1994 and 2055. A 100% increase means a doubling of the number of events.

Impact on Tree Fruit Production:
1a) Saturated soil in April - June limits tractor access, or results in deep ruts.
Potential Adaptations:

For new plantings:
___ Add drainage tile. Contact your local NRCS/FSA office for assistance.
___ Water diversion paths.
___ Ditches w/ flash flood riprap.

For existing plantings:
Even if the ground is saturated, sometimes you have to go in anyway.
___ Use light tank loads.
___ Wider or flotation tires may be an option for some tractors to reduce tire track damage.
___ Dual tire tractors.
___ Add drainage where possible.
___ Consolidate prunings in every other row to reduce tractor traffic for brush chopping.

Rut repair: (For when you have to get into the orchard despite damage to saturated soil).
___ Late summer rototilling of rutted areas, seed in with desirable alley vegetation, then stay off until next year. Thus you can only do alternate rows within the first year to retain access for harvest operations, and for the first spray trips of the next season.
___ An alternative option is filling in ruts with coarse sand or crushed rock/gravel.

Other tactics to reduce number of spray trips and rutting:

___ Monitor pest levels through foliar inspection, traps, and weather-based pest and horticultural tracking/prediction models to identify when pesticide application is needed, and when it can be avoided or delayed.

___ Alternate row sprays.

___ Use of apple scab fungicides with post-infection activity for more flexibility in spray timing.

___ Use trap-tree and perimeter-only insecticide sprays for plum curculio. This technique has been tested in research trials, but not fully validated in commercial use. It is not likely to eliminate need for full block spray trips at Petal Fall and First Cover for application of thinner and growth regulators, foliar nutrients, and/or for full block protection against Plum curculio, European apple sawfly, European red mite, leafminers, leafhoppers, apple scab, or other insect and disease pests.

___ Trap out apple maggot using red sphere traps around the orchard perimeter. However, this can be labor intensive and may not replace need for full block sprays for other reasons.

___ Border row sprays can replace full block sprays for apple maggot as long as there is no resident population inside. Therefore, intensive apple maggot monitoring is essential in this scenario.

___ Mating disruption for summer caterpillar pests (codling moth, obliquebanded leafroller, oriental fruit moth). However, mating disruption is only viable for blocks with relatively low initial populations and for larger contiguous blocks (i.e. 5+ acres). Full block, every row coverage may still be needed for other insect and disease pests.

___ Where possible, cutting back forest and other dense vegetation within 100+ feet of the orchard for air drainage and sunlight can also reduce pest pressure.

___ Maintain diverse, preferably native flowering plants in hedgerows to attract beneficial insects that may contribute to biological pest control in the adjacent orchard. These areas must not receive pesticide coverage through direct application or indirectly through drift.

___ Airplane or helicopter spray application service is not currently available at a feasible cost in New England. The return of airplane application does not seem likely, but drone application may eventually become available.

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Impact on Tree Fruit Production:

1b) Rapid fruit expansion – cracking.

Potential Adaptations:

___ High tunnels or other tree covers to keep fruit dry (especially for cherries, but also apples and peaches)

___ Raised beds and extensive orchard drainage prevent rapid uptake of water through the roots.

Review Questions:

What areas of my orchard and business operations most vulnerable to high intensity rains?

What are my highest priorities for cost-effective, “no-regrets”, adaptations?

Lower priority steps to reduce vulnerability:

Contact persons, existing assets, responsibility assignments, action steps, and timelines to reduce risk from high volume rain events:

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Resources:

U.S. Climate Resilience Toolkit Climate Explorer (U.S. Federal Government, 2018)
Maps, graphs, and data for estimated future frequency of +1, +2, and +3 inch rains within one day at county-level resolution.
https://noaa.maps.arcgis.com/apps/MapJournal/index.html?appid=8b910d9c7b9744ea94e07d82f5420782

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2. More frequent autumn rains

Total rainfall during September, October and November is expected to increase by 5% to 15% in most Northeastern U.S. tree fruit growing areas between 1994 and 2055. This represents about 1 inch extra average rain across those three months.

Impact on Tree Fruit Production:
2a) Fewer fair weather picking days for picking crews.
Potential Adaptations:
___ Larger crew so that work gets done in fewer days.
___ Platforms or other mechanical aid to increase picking rate from same number of pickers.
___ Longer workdays on the good days available.
___ Growth regulator applications to advance or prolong optimal fruit maturity for harvest over an extended period.

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Impact on Tree Fruit Production:
2b) Fewer optimal days for Pick Your Own sales.
Potential Adaptations:
___ More advertising, marketing, special events, alternate attractions to increase customer draw.
___ Rainproof attractions/activities. Tent coverage to reduce customer exposure.
___ Orchard floor maintenance to improve wet day customer comfort.
___ Closer or improved parking conditions. Add drainage or gravel to mud-prone parking and customer walkways.
___ Whole Farm Revenue Insurance.
___ Growth regulator applications to advance or prolong optimal fruit maturity for harvest over an extended period.
___ Experiment with new and different cultivars to spread PYO harvest over more weekends.

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Impact on Tree Fruit Production:
2c) Picking wet fruit increases bruising.
___ Bruising sensitivity after rain is cultivar specific. Pick harder apples following rain, delay picking softer varieties.
___ Bruising sensitivity varies with fruit maturity. Use starch iodine, DA meter, or other fruit maturity tests to identify when fruit is at optimal maturity for harvest.

Review Questions:

What areas of my orchard and business operations most vulnerable to frequent autumn rains?

What are my highest priorities for cost-effective, “no-regrets”, adaptations?

Lower priority steps to reduce vulnerability:

Contact persons, existing assets, responsibility assignments, action steps, and timelines to reduce risk from increased autumn rain:

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Resources:

Orchard Automation - Mobile Work Platforms
https://extension.psu.edu/orchard-automation-mobile-work-platforms

Fruit Harvest - Determining Apple Fruit Maturity
https://extension.psu.edu/fruit-harvest-determining-apple-fruit-maturity

Tree Fruit Maturity Indicators (apples, pears, plums)
https://extension.umaine.edu/fruit/harvest-and-storage-of-tree-fruits/maturity-indicators/

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3. Flooding (from either more intense rains or longer periods of rain, esp. in spring.)

Total rainfall during March, April and May is expected to increase by 10% to 15% in most Northeastern U.S. tree fruit growing areas between 1994 and 2055. This represents an extra 1.0 to 1.5 inches extra average rain across those three months. The increased frequency and intensity of high volume rain events exacerbates the risk of flooding and orchard soils too wet for tractor traffic.

Impact on Tree Fruit Production:

3a) Tree root anoxia

Potential Adaptations:

___ Site selection.
___ Rootstock selection.
___ Drainage tile.
___ Water diversion paths.
___ Ditches w/ flash flood riprap.
___ NRCS may provide design and 80% cost in some counties.
___ A drainage tile machine lowers installation cost, but must be done preplant and is site dependent because it does not work where there are large rocks or ledge.
___ Plant in raised beds or berms.
___ High tunnel covers over tree row?

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3b) Orchard road washouts

Potential Adaptations:

___ Water diversion units that go across roads to divert water flow (rock crusher belt). NRCS has specs. Water diversion units are better than 'water bars' because diversion units do not increase risk of bruising fruit during transport out of the orchard.
___ Larger culverts.
___ Gravel over culverts is more resistant to wash off than soil?

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3c) Nutrient leaching (vertical, below root zone and possibly into groundwater)

Potential Adaptations:

___ Site selection.
___ Fertigation through drip irrigation system.
___ Split nutrient applications. Midseason nutrient testing and application as is done with corn.
___ Optimize nutrient amounts through yearly tissue and soil testing.
___ Soil health improvements (e.g. increased organic matter, aggregates, microbes).
___ Planting site selection.

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3d) Nutrient runoff (horizontal, off-site)

Potential Adaptations:

Same as 3c for leaching, plus:

___ Orchard water flow direction through ditches, berms.

___ Construct a pond at lower end of slope to catch run-off water that could be used for irrigation.

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3e) Herbicide leaching (vertical, below root zone and possibly into groundwater)

Potential Adaptations:

___ Planting site selection.

___ Split herbicide applications to reduce load from any one application.

___ Optimize herbicide selection and dose through weed survey and target application timing and materials to identified priority weeds.

___ Soil health improvements (increase organic matter, soil aggregates, beneficial microbes).

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3f) Herbicide runoff (horizontal, off-site)

Potential Adaptations:

___ Orchard water flow direction through ditches, berms.

___ Do not use herbicide strip, allow some vegetation growth in tree row.

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3g) Herbicide degradation

Potential Adaptations:

___ Herbicide selection.

___ Rotate between different herbicide modes of action.

___ Precise herbicide timing relative to efficacy against key target weeds.

___ Pre-emergent vs post-emergent herbicide choice.

___ Spray adjuvants.

Review Questions:

What areas of my orchard and business operations most vulnerable to flooding?

What are my highest priorities for cost-effective, “no-regrets”, adaptations?

Lower priority steps to reduce vulnerability:

Contact persons, existing assets, responsibility assignments, action steps, and timelines to reduce risk from flooding:

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Resources:

NRCS Drainage Water Management
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/ny/technical/cp/?cid=nrcs144p2_027166

Fruit Tree Rootstocks for Michigan 2012 Apple, Pear, Peach, Cherry, Apricot, Plum
Includes notes on drought, flooding, and winter low temperature tolerance.
https://www.canr.msu.edu/hrt/uploads/535/78649/FruitTreeRootstocks-2012.pdf

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4. Drought

Drought manifests in different ways from short-term rain deficits to long-term soil moisture depletion caused by reduced rainfall and increased evapotranspiration due to warmer temperatures. The outlook for increased drought risk in Northeastern U.S. tree fruit growing areas is mixed. Overall, the observed number of months with extreme drought conditions has decreased in recent decades. The expected increase in summer precipitation between 1994 and 2055 will almost, but not quite, match the expected increases in evapotranspiration removal of soil water.

Overall, average annual soil moisture is expected to decrease in the Northeast, more in PA, NJ, and southern and western NY than in the Hudson Valley NY and New England. However, those are for the annual average. More concerning is the expected 20% to 25% increase in soil moisture variability between years. This would lead to increases in both flooding and drought risk. While the seasonal average values for soil moisture look relatively stable, there is a possible increase in the prolonged periods of summer rain deficit occurring at the same time as higher summer temperatures and evapotranspiration. This would increase the need for summer water supplementation through irrigation.

Impact on Tree Fruit Production:

4a) Tree desiccation. Delayed growth, reduced productivity, fruit quality, or tree death due to inadequate water supply.

Potential Adaptations:

___ Install irrigation before planting, or add irrigation to existing plantings.
___ Access to capital. Contact NRCS for design and financial support.
___ Improve soil health before planting.
___ Site selection.
___ Drought resistant rootstock selection, i.e. use larger rootstocks with deeper and larger root system. This could be a key, long-term adaptation measure.
___ Soil moisture monitoring with sensors. Independent or networked. Possible interference with mowing operations outside of herbicide strips.
___ Soil moisture and tree water needs estimated from local weather and ET/soil moisture model.
___ Optimize planting timing.
___ More complete vegetation control in herbicide strips to increase moisture penetration.

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4b) Tree desiccation. Insufficient water supply to run irrigation.

Potential Adaptations:

___ Increase farm pond water storage capacity.
___ Drill new well or improve existing well capacity.
___ Get water access rights from nearby river or pond.

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4c) Increased bitter pit.
Potential Adaptations:
___ Irrigation to stabilize and increase water supply.
___ Soil calcium supplements. However, this would only help if soil water were adequate.
___ Foliar calcium supplements.
___ Postharvest drench calcium supplement.
___ Improved general tree health through tissue and soil nutrient monitoring and corrective treatments.

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Resources:

Irrigation for Fruit and Vegetable Production – Penn State
Includes key irrigation periods for tree fruit crops.
https://extension.psu.edu/irrigation-for-fruit-and-vegetable-production

Northeast Irrigation Supply and Design Providers
https://extension.umaine.edu/agriculture/programs-by-topic/drought/northeast-irrigation-supply-design-providers/

Economics for Drip Irrigation in New York State
http://publications.dyson.cornell.edu/outreach/extensionpdf/1998/Cornell_AEM_eb9807.pdf

Cornell Apple Water deficit model
http://www.growingproduce.com/fruits/precision-irrigation-management-in-apples/

NRCS Drought -- Drought Resources
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/me/programs/financial/eqip/?cid=nrcseprd1300463

NRCS Irrigation -- Handbooks and Manuals
https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/irrigation/?&cid=stelprdb1045075

NRCS Environmental Quality Incentives Program (EQIP) profile (with local NRCS office locator)
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/eqip/?cid=stelprdb1044009

Irrigation - Best Management Practices for Agriculture in New Hampshire
Somewhat dated, but still good information.
https://www.des.nh.gov/organization/divisions/water/dwgb/water_conservation/documents/irrigation_bmps.pdf

Long-term Drought Effects on Trees and Shrubs
https://ag.umass.edu/landscape/fact-sheets/long-term-drought-effects-on-trees-shrubs

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Review Questions:

What areas of my orchard and business operations most vulnerable to drought?

What are my highest priorities for cost-effective, “no-regrets”, adaptations?

Lower priority steps to reduce vulnerability:

Contact persons, existing assets, responsibility assignments, action steps, and timelines to reduce risk from drought:

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5. Increased spring frost risk

Warmer temperatures in late winter and early spring lead to earlier initiation of spring growth and sensitivity to frost risk. If this earlier growth is followed by a final frost date that does not move earlier in the calendar at the same rate, then there is an increased risk of spring freeze damage to vegetative, and especially, fruit buds. Wolfe et al. 2018 estimated there could be a slightly increased risk in Northeastern U.S. for apple bud-killing frost events between Pink and Petal Fall bud stages during 2020−2040, with declining risk after 2040.

There are two types of spring freeze events: advection frost and radiation frost. An **advection frost** occurs when a cold air mass blows into the area bringing temperatures below the critical low threshold. This type of frost does not have a temperature inversion in which colder sir at the surface is trapped below warmer air aloft. There is not much a grower can do to protect against a freeze event once it is underway. Fortunately, advection frosts are less common than radiation frosts

A **radiation frost** occurs when clear night sky and calm winds allows energy loss from the ground and from fruit tree buds to create temperatures lower than that of air above the orchard. A wind of 5mph is usually enough to sufficiently mix the air layers to prevent the inversion that leads to a radiation frost. Without enough wind, there is insufficient mixing of the higher warmer air to alleviate the cold temperatures near the radiating ground surface. The colder air stays near the cooling surface because cold air is denser than warm air and thus does not rise. Several active practices exist for growers than can mitigate damage during radiation frost events

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Impact on Tree Fruit Production:
5a) Fruit buds damaged by low temperature.
Potential Adaptations:
<u>Advection Frost protection.</u>
___ Site selection (north facing slopes may delay bud break).
___ Site selection, elevation relative to local air drainage.
___ Cultivar selection for late bud break and late bloom date.
___ Foliar nutrient spray mix to increase frost hardness (such as the Warren Stiles formula).

<u>Radiation Frost protection.</u>
Same as above, plus
___ Overhead irrigation (but requires sufficiently large water source and delivery rate. Inadequate supply or delivery can increase frost damage.)
___ Drip irrigation to moisten soil before low temperature.
___ Overhead tree row canopies to reduce radiant heat loss?
___ Wind machines.
___ Helicopter service is not currently available in many Northeast orchard locations, but availability may increase in the future.

___ Portable heater units cycled through the orchard have been reported as helpful.
___ Wood or hay pile fires may or may not be effective. Smoke does not reduce frost risk, but a significant heat source may help by puncturing an inversion layer and creating updrafts to move air in the orchard. Smudge pots are not a viable option due to air pollution side effects.
___ Air drainage channels in orchard border
___ Frost protectant sprays (ice nucleation reduction).
___ Low temperature warning system
___ Orchard floor management – closely mowed ground cover in the orchard drive rows absorbs more heat during the day, and releases more heat to reduce frost damage the following night, providing up to 2F buffer against frost.

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Resources:

Spring Cold Injury to Winegrapes and Protection Strategies and Methods
Barclay Poling's landmark 2008 review of frost protection for grapes also applies to tree fruit.
https://journals.ashs.org/hortsci/view/journals/hortsci/43/6/article-p1652.xml#container-1826-item-1830

Understanding Frost & Freeze Events
(33 slides – overview of estimating risk and choosing protective measures.)
https://cpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/0/7265/files/2017/01/Fargione-Frost-and-Freeze-1-22-13-2n0kym4.pdf

Frost Protection – Tips and Techniques – 3 page summary.
https://cpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/0/7265/files/2017/01/frost-protection-tips-techniques-1qelzi6.pdf

Using sprinklers to protect plants from spring freezes – 2 page summary, nice wet bulb temperature start protection and sprinkler delivery rate tables.
http://msue.anr.msu.edu/news/using_sprinklers_to_protect_plants_from_spring_freezes

Critical Temperatures for Frost Damage on Fruit Trees (budstage temperature charts)
https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1643&context=extension_curall

Principles of Frost Protection – 23 page technical bulletin from University of California.
http://biomet.ucdavis.edu/frostprotection/Principles%20of%20Frost%20Protection/FP005.html

Frost Protection: Fundamentals, Practice, and Economics – Volume 1 (Comprehensive, book length detail).
http://www.fao.org/docrep/008/y7223e/y7223e00.htm#Contents

Orchard Frost - Assessing Peach Bud Injury
https://extension.psu.edu/orchard-frost-assessing-peach-bud-injury

Orchard Frost - Assessing Fruit Bud Survival
https://extension.psu.edu/orchard-frost-assessing-fruit-bud-survival

Climate change is already hurting fruit breeders, and consumers could soon feel the pain

Newspaper article that provides a good overview of the impact of climate change on tree fruit production in the eastern U.S. through increased frost risk and lack of chilling hours.
https://www.washingtonpost.com/lifestyle/home/climate-change-is-already-hurting-fruit-breeders-and-consumers-could-soon-feel-the-pain/2019/03/27/6d5252fa-36c2-11e9-854a-7a14d7fec96a_story.html

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Review Questions:

What areas of my orchard and business operations most vulnerable to spring frost?

What are my highest priorities for cost-effective, "no-regrets", adaptations?

Lower priority steps to reduce vulnerability:

Contact persons, existing assets, responsibility assignments, action steps, and timelines to reduce risk from spring frost:

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6. Extreme winter low temperatures

Even with overall global warming, there is evidence supporting the hypothesis that the loss of Arctic Sea ice may play a role in destabilizing the circumpolar jet stream winds that normally prevent cold Arctic air masses from reaching down into the mid-latitudes of the Northeast. In this hypothesis, which is still being studied and is not "settled science", cold air excursions into the Northeast from the polar region may be increasing in frequency or intensity, and thus increasing the chance of a severe winter deep freeze. Depending on the location of these air mass movements, they can also lead to winter and spring temperatures much warmer than average. With increased variability, a period of relatively warm temperatures followed by severe cold that could damage fruit trees. Thus, even with warmer winter temperatures on average, increased winter temperature *variability* in the Northeastern U.S. could interfere with fruit trees' natural winter dormancy and resistance to cold.

Impact on Tree Fruit Production:

6a) Freeze damage to trunk cambium

Potential Adaptations:

___ Site selection.
___ Wind breaks.
___ Paint trunks with white latex paint to prevent southwest injury.
___ Nutrient applications to prevent and to counteract existing vascular system damage.
___ Lightly crop trees in the following year to aid in recovery?

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6b) Freeze damage to root systems

___ Mulching within tree row for better root insulation. This may seem to conflict with minimizing ground cover to provide buffer against spring frost damage. But the mention of reduced orchard ground cover to buffer spring frost risk is for the entire orchard floor, not the tree row area containing majority of root systems.
___ Nutrient applications to prevent and to counteract root system damage.

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Resources:

Preparing Trees for Winter. University of Maine factsheet.
https://extension.umaine.edu/fruit/growing-fruit-trees-in-maine/preparing-trees-for-winter/

Tree Fruit Cold Hardiness - Pruning Effects. Penn State University factsheet.
https://extension.psu.edu/tree-fruit-cold-hardiness-pruning-effects

Tree Fruit Cold Hardiness - Effect of Pruning. Penn State University factsheet.
https://extension.psu.edu/tree-fruit-cold-hardiness-effect-of-pruning

Tree Fruit Cold Hardiness - Pruning Peach Trees with No Crop. Penn State University factsheet.
https://extension.psu.edu/tree-fruit-cold-hardiness-pruning-peach-trees-with-no-crop

Fruit Tree Rootstocks for Michigan 2012 Apple, Pear, Peach, Cherry, Apricot, Plum
https://www.canr.msu.edu/hrt/uploads/535/78649/FruitTreeRootstocks-2012.pdf

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Review Questions:

What areas of my orchard and business operations most vulnerable to winter cold temperature damage?

What are my highest priorities for cost-effective, "no-regrets", adaptations?

Lower priority steps to reduce vulnerability:

Contact persons, existing assets, responsibility assignments, action steps, and timelines to reduce risk from winter cold temperature:

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7. Winter chill unit reduction

Fruit trees require accumulation of chill hours to reach maximum dormancy for protection against winter minimum temperatures and normal physiological function the following spring.

Impact on Tree Fruit Production:
7a) Uneven bloom, reduced fruit set, reduced return bloom, lower productivity or fruit quality.

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The text excerpt below was written for stone fruit, but in general is applicable to pome fruit as well. The text was adapted from a Texas A&M factsheet by Byrne and Bacon (undated, see references section for citation and link.)

> **Delayed Foliation**. A classic symptom of insufficient chilling is delayed foliation. A tree may have a small tuft of leaves near the tips of the stems and be devoid of leaves for 12 to 20 inches below the tips. Lower buds will break eventually but full foliation is significantly delayed, fruit set is reduced, and the tree is weakened. Furthermore, heavy suckering from lower parts of the tree causes management problems, and normal development of next year's fruit buds can be impaired.
> **Reduced Fruit Set and Buttoning.** Flowering, in response to insufficient chilling, often follows the pattern seen with leaf development. Bloom is delayed, extended, and due to abnormalities in pistil and pollen development, fruit set is reduced. In many peach cultivars, flowers drop before or around shuck split, but in others such as 'Jersey Queen' and 'Harvester', buttons form. Buttons result from flowers which apparently have set but never develop into full-size fruit. The fruit remains small and misshapen as they ripen. If you cut these fruit open, the seed is dead. Because buttoning is not apparent early in the season, growers cannot thin off the abnormal fruit and the developing buttons serve as a food source and overwintering site for insects and diseases.
>
> **Reduced Fruit Quality.** The effects on leaf growth and fruit set are dramatic but the effects of insufficient chill on fruit quality are subtle, and can occur when other symptoms do not. Insufficient chilling will cause many cultivars to have an enlarged tip and reduced firmness. Furthermore, fruit ground coloration may be greener than usual, possibly due to the fruit losing firmness before the ground color can fully change from green to yellow. The extent of these quality problems depends on the cultivar and the degree of chilling deficiency.
>
> **Chill unit accumulation**
> The question of what is dormancy and what constitutes 'chilling temperatures' has yet to be clearly defined. Most people agree that temperatures below freezing or above 60 degrees F are not effective for chilling unit accumulation. There are various models used to calculate chilling, each one defining what a chilling unit is. The Utah model is commonly used for tree fruit. The Utah method includes the concepts of relative chilling effectiveness and negative chilling accumulation (or chilling negation).

Utah Model (Richardson et al. 1974)
1 hour below 34 degrees F = 0 chill units
1 hour 35-36 degrees F = 0.5 chill units
1 hour 37-48 degrees F = 1.0 chill units
1 hour 49-54 degrees F = 0.5 chill units
1 hour 55-60 degrees F = 0 chill units
1 hour 61-65 degrees F = −0.5 chill units
1 hour >65 degrees F = −1.0 chill units

End of excerpt
****

Projections out to 2050 suggest that even with warmer winter temperatures, New England and northern New York are not at risk of inadequate number of chilling hours to meet requirements for even the most demanding apple cultivars. However, southern areas of the Northeast (e.g. MD, NJ, PA, and WV) may experience an increasing percentage of winters that do not reach a 1000-1200 cumulative chilling hours (as defined by the Utah model). Similarly, major apple production regions such as Michigan or Washington could fall below chilling hour requirements for optimum production of some apple cultivars in the coming decades, and open a market niche for production of those cultivars in areas of the Northeast that still have sufficient chilling hours.

Potential Adaptations:

___ Site selection (to maximize chilling hours where otherwise limited).
___ Cultivar selection.
___ Plant growth regulator application to control release from dormancy have been used for stone fruit in California. Applicability for stone fruit in other regions and for pome fruit is uncertain.
___ Track winter chilling hours (i.e. through online weather model), delay pruning until after 1200 chill units (Utah Model) accumulated.

****

7b) Opportunity: Less severe winter low temperatures.

Winter minimum temperatures are increasing faster than maximum or minimum temperatures for all other seasons. This may create potential for northward range expansion for peach and other stone fruit into areas where winter minimum temperatures are currently too low. But increased variability in winter temperatures may result in little change in the minimum temperatures tree fruit rootstocks and cultivars will have to withstand. An attempt at growing cherry trees in hoop house to avoid winter low temperatures in Maine was not successful.

Potential Adaptations:

___ It may be possible to increase plantings of peaches, and other stone fruit in locations not formerly suitable due to winter low temperatures. But ***average*** winter low temperature values are not the critical factor. A single cold night may cause winter kill. Moreover, it is the risk over multiple years of the life of the tree, not the annual minimum value, that controls the long-term viability of a tree species in a location. Thus, if the lowest ***decadal*** minimum temperature is not increasing, then stone fruit range expansion may not be an option. The USDA Plant Hardiness Zone map is designed shows the recently observed 30-year minimum winter temperature.

****

Resources:

USDA Plant Hardiness Zone Interactive Map
https://planthardiness.ars.usda.gov/phzmweb/interactivemap.aspx

---

Review Questions:

What areas of my orchard and business operations most sensitive to warmer winter temperatures?

What are my highest priorities for cost-effective, “no-regrets”, adaptations?

Lower priority steps to reduce vulnerability:

Contact persons, existing assets, responsibility assignments, action steps, and timelines to reduce risk from to warmer winter temperatures:

****

8. Warmer, longer growing season

Impact on Tree Fruit Production:

8a) Potential horticultural effects.

Apples, peaches and other tree fruits require a semi-fixed number of days on the tree to reach maturity, but many cultivars need cool fall nights (with a differential between daily high and low temperature) to color, so fruit quality may not be favored by a longer growing season, at least for the cultivars currently grown. For those culitvars, warmer growing season temperatures may lower total production or fruit quality. However, longer growing season may allow expansion of cultivar selection to include those that require more cumulative heat units than locations currently provide.

Potential Adaptations:

___ Longer season cultivars may become suitable.
___ May need to shift away from current cooler-adapted cultivars.
___ Use of plant growth regulators may delay ripening on cultivars adapted to cooler climates to time ripening with the later onset of cooler weather.

****

8b) Potential increase in insect, disease, and weed pest pressure.

Potential effects include: Additional pest generations; Higher pest overwintering survival, or new pest species; Pest – predator/parasitoid synchrony disruption; Increase of invasive pest risks.

Potential Adaptations:

___ Ongoing education to stay up to date with current pest threats, monitoring, and management information.
___ Pest management advisory services.
___ Decision support tools such as weather-based pest timing and severity forecasts.

****

8c) Potential increase in pest resistance to pesticide

This could occur if a changed climate leads to increased spray frequency, increase in number of pest generations per year, or causes effects on pesticide efficacy that lead to increased chance of pesticide resistance.

Potential Adaptations:

Resistance management tactics

___ Reduce number of sprays by use of monitoring and thresholds.

___ Select alternate pesticide modes of action.

___ Conserve natural pest controls through orchard management (e.g. unsprayed alternate host areas)

___ Conserve natural pest controls through pesticide selection and timing.

___ Better spray coverage through higher water volume.

___ Better coverage through pattern monitoring to optimize nozzle type (air-induction vs. disc/core, spray pattern width), nozzle volume, fan speed, fan-air direction, sprayer travel speed, etc.

****

Resources:

U.S. Climate Resilience Toolkit Climate Explorer (U.S. Federal Government, 2018)

Maps, graphs, and data for estimated future number of growing degree days per year at county-level resolution. Works best by entering your county name.
https://noaa.maps.arcgis.com/apps/MapJournal/index.html?appid=8b910d9c7b9744ea94e07d82f5420782

What will climate feel like in 60 years?

Visualizations showing how the future climate of a specified location will resemble the climate of different geographic areas in the present.
https://fitzlab.shinyapps.io/cityapp/

A Vision for Apple Orchard Systems of the Future
http://nyshs.org/wp-content/uploads/2016/10/Pages-11-16-from-NYFQ-Book-Fall-2013-5.pdf

Apple cultivars https://extension.psu.edu/apple-cultivars

Apple Rootstocks: Capabilities and Limitations - Penn State 2018 update
https://extension.psu.edu/apple-rootstocks-capabilities-and-limitations

High Density Apple Orchard Management
https://content.ces.ncsu.edu/high-density-apple-orchard-management

Cornell-Geneva Apple Rootstocks for Weak Growing Scion Cultivars
http://nyshs.org/wp-content/uploads/2015/03/21-24-Robinson-Pages-NYFQ-Book-Spring-2015.eg-4.pdf

Fruit Tree Rootstocks for Michigan 2012 Apple, Pear, Peach, Cherry, Apricot, Plum
https://www.canr.msu.edu/hrt/uploads/535/78649/FruitTreeRootstocks-2012.pdf

Trellis Support Systems for High Density Apples
http://www.hort.cornell.edu/expo/proceedings/2017/TreeFruit%20Weather.%20Trellis%20Support%20Systems%20for%20High-Density%20Apples.pdf

Fruit Harvest - Handling of Frozen Apples

A shift to later maturing cultivars to take advantage of longer growing season could result in fruit freezing before harvest with uneven extension of frost free period.
https://extension.psu.edu/fruit-harvest-handling-of-frozen-apples

---

Review Questions:

What areas of my orchard and business operations with highest risk or opportunity from longer, warmer growing season?

What are my highest priorities for cost-effective, "no-regrets", adaptations?

Lower priority, longer term steps to reduce vulnerability:

Contact persons, existing assets, responsibility assignments, action steps, and timelines to reduce risk and take advantage of opportunities from longer, warmer growing seasons:

****

9. Increased frequency of 90+ F temperatures: Effects on people.

Impact on Tree Fruit Production:

9a) Worker heat stroke.

Potential Adaptations:

___ Cooling stations.
___ Work scheduling to avoid heat of the day.
___ Platforms or other tools to reduce harvest labor.

****

9b) Reduced Pick Your Own traffic.

Potential Adaptations:

___ More advertising, marketing, special events, alternate attractions to bring in customers.
___ Tent coverage and access to air conditioning to reduce customer exposure.
___ Customer education about harvest season timing.
___ Fruit maturity delay with growth regulators.

****

Resources:

Excessive heat, a 'silent killer' Heat exhaustion or heatstroke? Know the signs of heat illness.
https://www.noaa.gov/stories/excessive-heat-silent-killer

Heat Index
https://www.weather.gov/safety/heat-index

U.S. Climate Resilience Toolkit Climate Explorer (U.S. Federal Government, 2018)

Maps, graphs, and data for estimated future number of days per year with temperature over 90 degrees F (and other thresholds) at county-level resolution. Works best by entering your county name.
https://noaa.maps.arcgis.com/apps/MapJournal/index.html?appid=8b910d9c7b9744ea94e07d82f5420782

Review Questions:
What areas of my orchard and business operations most vulnerable to longer, warmer growing season horticultural and pest threats, or most open to benefit from longer growing seasons?

What are my highest priorities for cost-effective, "no-regrets", adaptations?

Lower priority steps to reduce vulnerability:

Contact persons, existing assets, responsibility assignments, action steps, and timelines to reduce risk from heat stress to orchard workers and pick-your-own customers:

****

10. Increased frequency of 90+ F temperatures: Effects on fruit and trees.

Impact on Tree Fruit Production:
10a) Sunburn and Sunburn browning. (The two types of damage have distinct causes and prevention, and both distinct from photo-oxidative sunburn which is not temperature related).

Potential Adaptations:
___ Overhead shade system. Hail nets can also serve to reduce sunburn.
___ Overhead irrigation to cool fruit and reduce sensitivity.
___ Automated mist cooling
___ Application of Surround (kaolin clay) to reduce canopy and fruit surface temperatures.
___ Other sunburn protectant sprays.
___ Drip irrigation to reduce sensitivity by maintain optimum water access to fruit trees, and by cooling the orchard through evaporation of soil moisture
___ Summer pruning timing.

****

10b) More bitter rot.
Sunburn damage due to high temperatures, esp. over 95F, has been correlated with increased bitter rot damage.
Potential Adaptations:
___ Include bitter rot in nutrient management planning (which nutrients help? Need link).
___ Monitoring and fungicide selection to reduce bitter rot.
___ Sunburn prevention measures as shown in 10a.
****

10c) Rapid fruit maturation.
Potential Adaptations:
___ Crop load management.
___ Growth regulator applications.
___ Fruit maturity monitoring and forecasting.

****

10d) Postharvest fruit heating in bins.
Potential Adaptations:
___ Bin covers or shaded placement
___ Optimize harvest operations to minimize time between field and storage.
___ Increase rapid cooling capacity, expedited removal of field heat. However, hydro coolers bring their own set of problems.

****

10e) Increased cooling load on storage
Potential Adaptations:
___ Better storage insulation
___New or upgraded storage cooling units

****

10f) Temperature induced fruit quality, color, or storage disorders (such as increased storage scald, internal breakdown, water core)
Potential Adaptations:
___ Growth regulator application or nutrient application.
___ Fruit cooling with overhead irrigation or shade cloth.
___ Storage monitoring and atmosphere management.
___ Internal fruit quality monitoring and pre-storage sorting.

****

10g) Warm or erratic autumn temperatures can interfere with establishing winter dormant resistance to cold.
Potential Adaptations:
___ Rootstock and cultivar selection for greater resistance to low winter temperatures. Differences among rootstocks and cultivars with respect to autumn temperature variations are not clear, but ratings of overall susceptibility to damage from winter low temperatures are available for many rootstocks and cultivars.
___ Site selection.
___ Weather monitoring and model estimate of hardening off status prior to pruning.
___ Delay start of winter pruning.
****

Resources:

Sunburn Management in Apples

http://treefruit.wsu.edu/article/sunburn-management-in-apples/

The factsheet listed above is a short summary of the journal article listed below. The full journal article in not available through open access, but well worth getting a copy through Extension or university library. It cannot be linked to this document due to copyright.

Source article: Racsko & L. E. Schrader. 2012. Sunburn of Apple Fruit: Historical Background, Recent Advances and Future Perspectives. Critical Reviews in Plant Sciences, 31:6, 455-504. DOI: 10.1080/07352689.2012.696453

Apple PGRs - Shifting Harvest Window of Gala a Risk in Warmer Climates

https://extension.psu.edu/apple-pgrs-shifting-harvest-window-of-gala-a-risk-in-warmer-climates

U.S. Climate Resilience Toolkit Climate Explorer (U.S. Federal Government, 2018)

Maps, graphs, and data for estimated future number of days per year with maximum temperature over 95 degrees F. Sunburn can occur at temperature as low as 86F, but at typical relative humidity, solar radiation, and wind speed, damage threshold is not reached until about 95F. The web page shows values at county-level resolution, and works best by entering your county name.

https://noaa.maps.arcgis.com/apps/MapJournal/index.html?appid=8b910d9c7b9744ea94e07d82f5420782

Review Questions:

What areas of my orchard and business operations most vulnerable to heat stress effects?

What are my highest priorities for cost-effective, “no-regrets”, adaptations?

Lower priority steps to reduce vulnerability:

Contact persons, existing assets, responsibility assignments, action steps, and timelines to reduce risk from increased number of days with high temperatures.

****

11. Increased frequency of severe weather

Impact on Tree Fruit Production:
11a) Severe wind: Broken graft union and limbs.
Increased fire blight exposure through wind damaged wounds. Damage to trellis system.
Damage to deer fence.
Potential Adaptations:
___ Site selection.
___ Stronger trellis designs.
___ Planting semi-dwarf rootstocks with improved anchorage characteristics.
___ Wind breaks.
___ Quick recovery plan in place to reset trees.
___ Materials, tools and labor available for rapid repair to trellis systems and deer fencing.
___ Stronger and better anchored tree supports.
___ Additional wires and closer wire spacings, re-tieing trees to wires.

****
11b) Hail.
Potential Adaptations:
___ Hail net.
___ Scatter varieties across locations to diffuse these risks.
___ Multiple growing sites to spread risk from hail and freeze events.

****
Resources:
Salvaging Wind Damaged Apple Trees
https://extension.umaine.edu/ipm/wp-content/uploads/sites/44/2019/05/Salvaging-Wind-Damaged-Apple-Trees.pdf

Drape Net a viable option for orchard protection
https://fruitgrowersnews.com/article/drape-net-a-viable-option-for-orchard-protection/

Impact of exclusion netting row covers on arthropod presence and crop damage to 'Honeycrisp' apple trees in North America: A five-year study
https://www.sciencedirect.com/science/article/pii/S0261219417301035

Impact of various types of anti-hail nets on light exposure in orchards and quality parameters of apples – a review (Hungarian article translated to English)
https://www.researchgate.net/publication/309623554_Impact_of_various_types_of_anti-hail_nets_on_light_exposure_in_orchards_and_quality_parameters_of_apples-_a_rewiev

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Review Questions:

What areas of my orchard and business operations most vulnerable to severe weather?

What are my highest priorities for cost-effective, “no-regrets”, adaptations?

Lower priority steps to reduce vulnerability:

Contact persons, existing assets, responsibility assignments, action steps, and timelines to reduce risk from wind and hail:

****

Other topics related to climate risk

Access to capital

12a. Potential Adaptations:

___ NRCS cost sharing.

___ FSA loans.

___ Consider alternatives to taking on too much debt, as this can affect your ability to be nimble and adapt strategically to changes in weather, markets, or other conditions. Maintain financial agility, so you can weather the bad years.

___ Consider planting extensive, lower tree density semi-dwarf systems with reduced upfront installation costs

Diversification and spreading risk

12b. Potential Adaptations:

___ Adjust selection of crops, varieties, or markets.

___ Adjust emphasis on secondary vs. primary products (e.g. reduce focus on apples and cider, and increase marketing focus on apple cider donuts, baked goods, and other secondary products.)

___ Increase emphasis on diversified retail sales. With a high revenue farm store, the orchard becomes more of an aesthetic sales tool vs. a production area. Thus, orchard production risk becomes less of a risk factor for the overall enterprise.

___ Pick your Own vs. Farm stand, Farmers' markers, Direct to Retail, Wholesale warehouse.

___ Crop insurance.

___ Where applicable, woodlot harvest can serve as a buffer for irregular tree fruit crop returns. This can be economically viable if the interval between crop problems is no more than about once per decade. Infrequent woodlot harvests can exceed costs if suitable lot sizes, growth potential, and forest manage practices are available. Appending woodlots to orchards in this way is only practical in more remote areas where land prices and taxation are suitable.

Regulatory, Market, and Economic changes

Impact on Tree Fruit Production:

12c. Increased cost for fossil fuels, electricity and other forms of energy.

Potential Adaptations:

___ More efficient engines.

___ Electric tractors

___ Solid set "fixed" canopy spray systems.

Other methods to reduce the number of tractor trips through the orchard. See "Other tactics to reduce number of spray trips" for "High volume rain events" on page 5.

___ Increase energy use efficiency for cooling units

___ Increased storage insulation.

___ Make use of lower off-peak electricity costs.

___ On-farm solar or wind energy generation.

12d. Changes in tree fruit production in other regions of the U.S., and in other countries will affect the availability and pricing of competing fruit to supply wholesale and retail customers currently served by Northeastern tree fruit growers. Conversely, new customer outlets may become available to Northeastern growers.

****

Resources:

Crop insurance

Crop insurance protects farmer's crop yield or revenue from a wide range of adverse weather conditions such as drought, excess moisture, frost, freeze, etc. Failure of irrigation or water supply due to drought is also an insured type of loss. It is best to be proactive and sign up for crop insurance ahead of time. If you wait until after the loss has occurred, recovery options and coverage are more limited.

Find a local crop insurance agent
https://prodwebnlb.rma.usda.gov/apps/AgentLocator/#/

Northeast Apple crop insurance summary: https://extension.umaine.edu/agriculture/wp-content/uploads/sites/14/2018/05/Intro-to-Apple-Crop-Insurance.pdf

Northeast Peach crop insurance summary: https://extension.umaine.edu/agriculture/wp-content/uploads/sites/14/2018/05/Intro-to-Peach-Crop-Insurance.pdf

Farm Service Agency – County Office locator
Source for loans and also for crop insurance premium quotes.
https://offices.sc.egov.usda.gov/locator/app

USDA (NRCS, FSA, etc.) support programs

Agricultural Conservation: A Guide to Programs - Updated August 15, 2019

The Natural Resources Conservation Service (NRCS) and the Farm Service Agency (FSA) in the U.S. Department of Agriculture (USDA) currently administer over 20 programs and subprograms that are directly or indirectly available to assist producers and landowners who wish to practice conservation on agricultural lands. The number of these programs and the differences among them have created some confusion about the purpose, participation, and policies of the programs. This document provides basic information for each of the programs.
https://fas.org/sgp/crs/misc/R40763.pdf

Review Questions:

Highest priorities for action in these areas:

Contact persons, existing assets, responsibility assignments, timelines, and action steps for access to capital, diversification, fossil fuel prices, and market changes related to changing climate:

III) Adaptation considerations

Users of this checklist are directed to Chapter 4, pages 32 – 41, of "Adaptation Resources For Agriculture: Responding to Climate Variability and Change in the Midwest and Northeast" (Janowiak et al. 2016) for a full discussion of adaptation planning considerations and methods. That publication is available for free online at https://www.climatehubs.oce.usda.gov/archive/sites/default/files/adaptation_resources_workbook_ne_mw.pdf

Adaptations that involve major infrastructure or other investments or significant changes to personnel, operations, marketing or other defining aspects of the farm have ramifications far beyond weather readiness. Major changes can bring added and perhaps unwelcome layers of complexity to running a farm. But flex points in the life of a business can also provide more expansive opportunity for change (Swanston et al., 2016).

Setting reasonable and concrete objectives by using the S.M.A.R.T. method (as reviewed by White, 2018) can increase the chance for successfully achieving your goals.

S M A R T is an acronym for:

Specific = Describes an action, behavior, outcome, or achievement that is observable.

Measurable = Quantifiable indicator(s) of progress towards meeting the goal.

Audience = Identifies who or what will be affected.

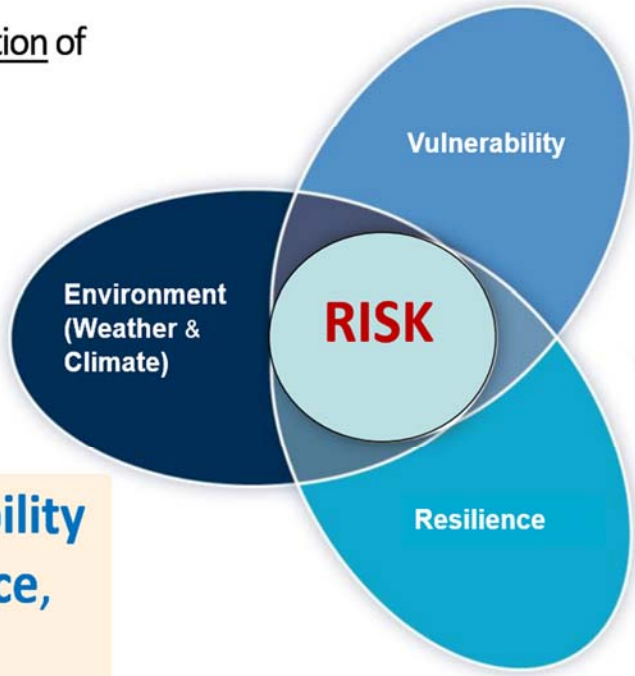
Relevant = Meaningful, realistic, and reasonably ambitious.

Timebound = A specific time frame for activation.

The graphics on the following pages are copied from the "Farmer Response to Changing Weather (Adaptation)" slide presentation that accompanies this curriculum. They are included here to provide a very brief introduction to adaptation planning topics that are covered in much greater and useful detail in "Adaptation Resources For Agriculture" (Janowiak et al. 2016).

Risk level is not dictated by the environment

Risk to your farm is a combination of
Environment,
Vulnerability, &
Resilience.



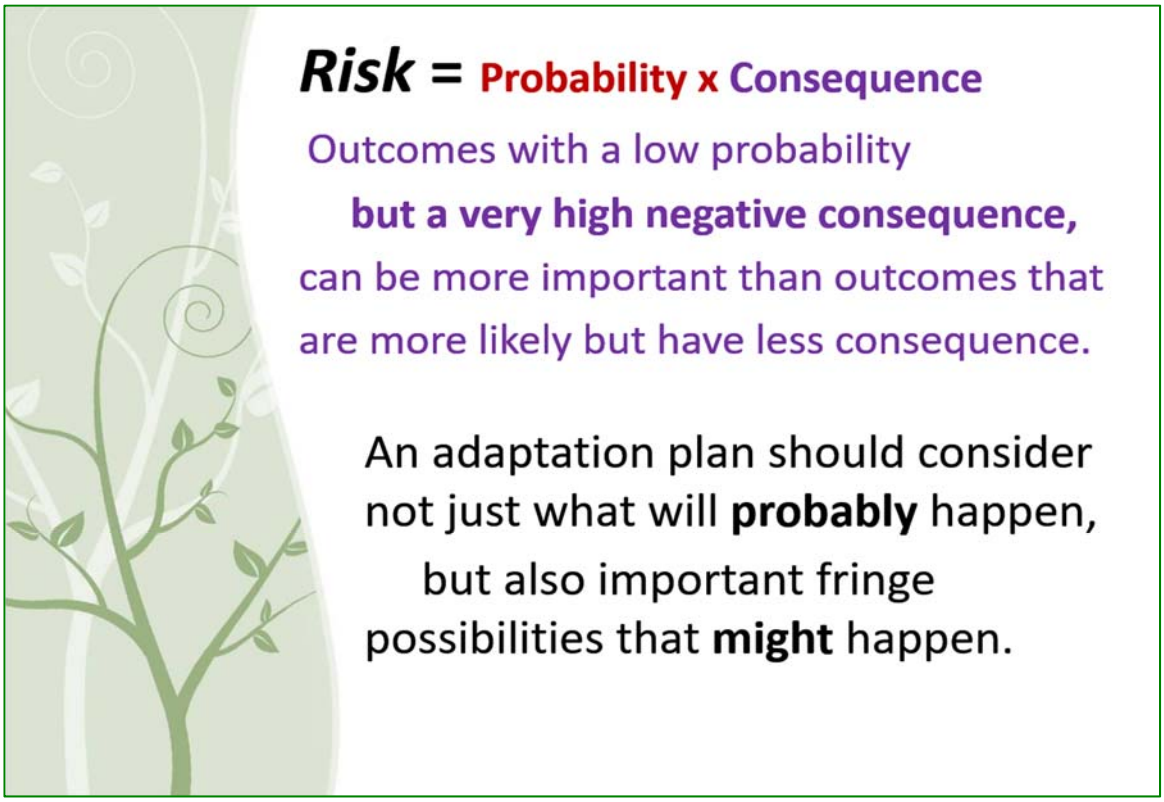
By reducing **Vulnerability** and building **Resilience**, **you can reduce Risk.**

From IPCC, 2012: Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 1-19.

Key Questions:

- What management challenges or opportunities might occur?
- Can current management meet management goals?
- Do goals need to change?

Adapted from Janowiak et al., 2016. Adaptation Resources for Agriculture. https://www.climatehubs.oce.usda.gov/archive/sites/default/files/adaptation_resources_workbook_ne_mw.pdf

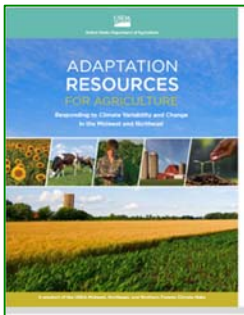


Adaptation strategies

Resistance – Prevent a change in conditions from having an effect.
Ex. Install irrigation, Strengthen structures to resist high winds.

Resilience – Being able to recover from a damage event and get back to previous operations. Ex. Crop insurance, Spread risk by diverse crops.

Replacement – Change operations to better fit with new conditions.
Ex. New crops or income stream, Switch from wholesale to retail.



Adaptation Resources for Agriculture

← Planning time frame and intensity →

Spontaneous | **Intentional** | **Transformational**

Automatic, unplanned	⟶	Intentional, purposeful, planned
Reactive to observed change	⟶	Responsive to accommodate future change
Reduces current risk	⟶	Reduces risk and expands new opportunities

Adapted from Janowiak et al., 2016. Adaptation Resources for Agriculture.
https://www.climatehubs.oce.usda.gov/archive/sites/default/files/adaptation_resources_workbook_ne_mw.pdf

'Taking what comes'
is unlikely to result in optimum outcomes.

Not deciding is also a choice.

When benefits are uncertain,
or if there are irreversible costs
for taking action now, then
getting more information may be the best first step.

Use available resources.
You are not in this alone.

Uncertainty

It is difficult to make plans when the specific issues are undefined:

* How will the weather change?
* What effect will those changes have on your farm enterprise?

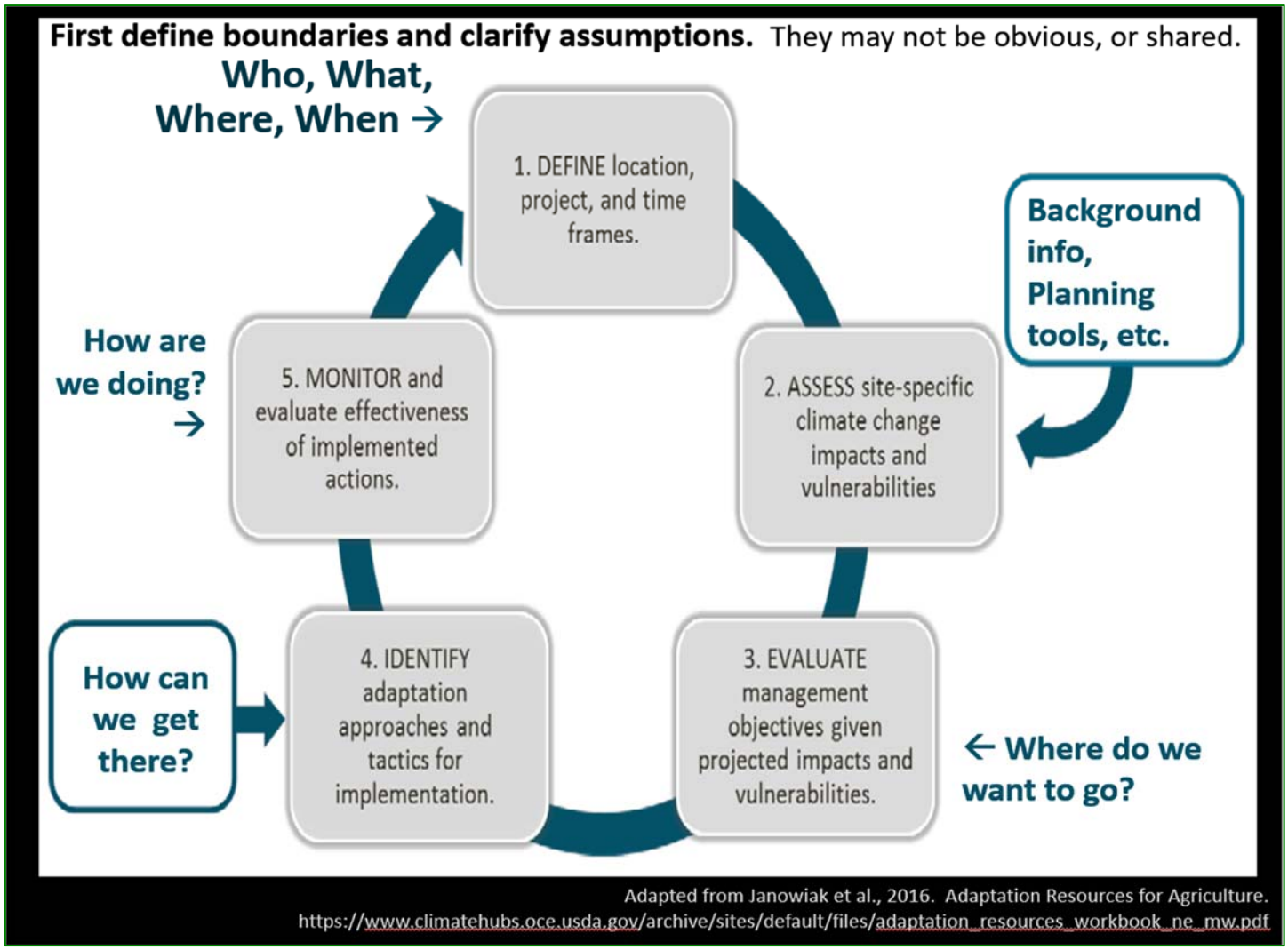
But you make decisions and act under uncertainty every day.

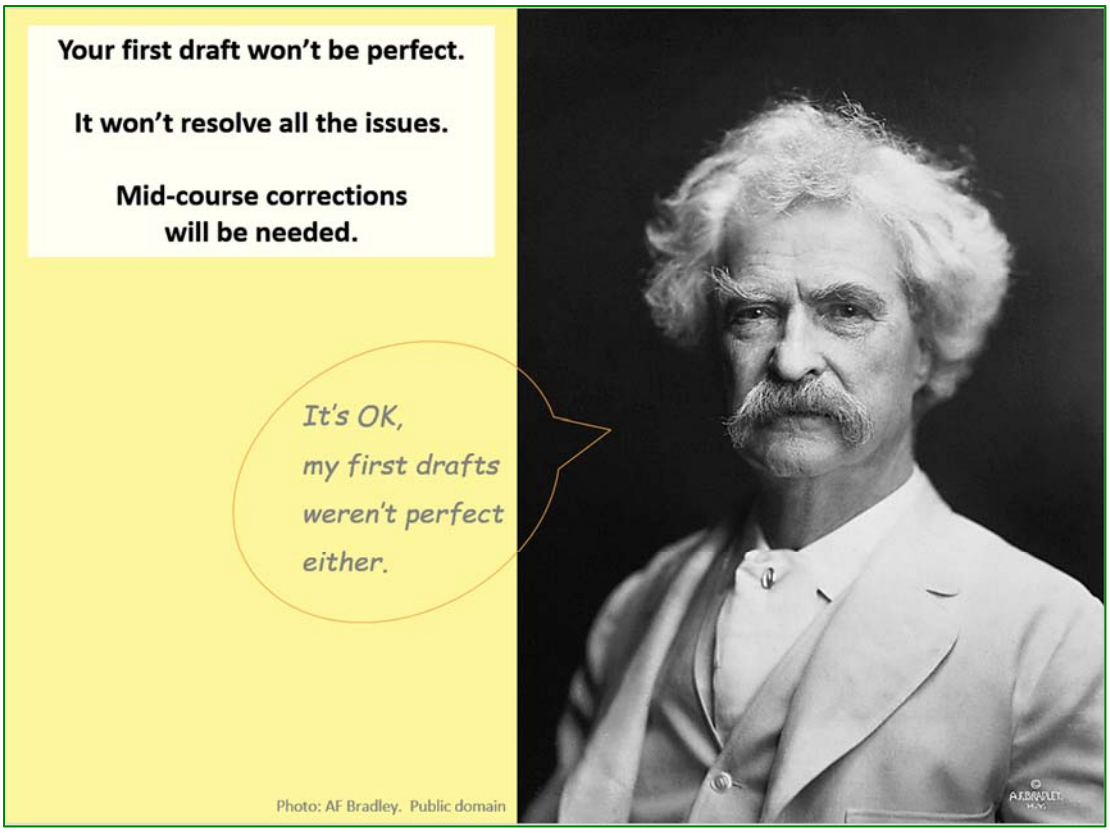
Information does not have to be perfect to **reduce uncertainty** and **improve decisions**.

Most of adaptation to changing weather consists of **skills and abilities**

you already have.

Adaptation planning as a repeating cycle





"The secret
of getting started
is to break complex
overwhelming tasks,
into small manageable tasks,
and then starting
on the first one".

~ Mark Twain

Table 1. Summary of Vulnerabilities and Adaptation priorities

WEATHER CHANGE	Areas of my orchard business most vulnerable	Highest priorities for cost-effective adaptations
High volume rain events		
More frequent autumn rains		
Flooding		
Drought		
Spring frost risk		
Extreme winter low temperature		
Winter chill unit reduction		
Warmer, longer growing season		

WEATHER CHANGE	Areas of my orchard business most vulnerable	Highest priorities for cost-effective adaptations
Increased frequency of 90+F temperatures		
Increased frequency of severe weather		
Access to capital		
Diversification		
Regulatory, Market, Economic changes		

Table 2. Summary of Contact persons, existing assets, responsibility assignments, action steps and timelines.

WEATHER CHANGE	Contact persons, existing assets, responsibility assignments, action steps and timelines.
High volume rain events	
More frequent autumn rains	
Flooding	
Drought	
Spring frost risk	
Extreme winter low temperature	
Winter chill unit reduction	
Warmer, longer growing season	

WEATHER CHANGE	Contact persons, existing assets, responsibility assignments, action steps and timelines.
Increased frequency of 90+F temperatures	
Increased frequency of severe weather	
Access to capital	
Diversification	
Regulatory, Market, Economic changes	

IV) Supplement - Research Topics for tree fruit adaptations to changing weather

This supplement was added to help growers and researchers build a list of unanswered questions that might benefit from research. Reading this sections is secondary and unnecessary for using the checklist and adaptation considerations in the main section of the workbook. The numbers refer to section within the checklist for that topic.

1a. Saturated ground

___ Drones to apply pesticide and/or growth regulators on a commercial scale, either by contractor or by farmer owned equipment.

___ Potential for ground spray trip reduction through fixed spraying systems. NRCS might help subsidize this as a soil conservation measure if applied research gets it to commercial viability.

___ Mechanical thinning devices are lighter than loaded sprayer. However, mechanical thinning is still unproven and needs refinement. In addition to reducing tractor traffic, it offers a way to address chemical uses concern for carbaryl.

___ What trellis design system considerations do you need to plan for extreme & heavy precipitation, considering soil and site specifics?

___ Same as above, but for Fence systems. Is this information out there?

___ How do orchard tire & tractor setups interact with wet soil and compaction? Tire widths, ruts, soil types.

___ Do orchards need wider spaces between rows?

___ Could extensive, free-standing training systems be more resilient to soil compaction and excessive rainfall events?

___ Drones for pesticide, growth regulator and nutrient applications.

___ Significance of ruts, soil compaction, and other possible soil damage caused by tractor traffic on saturated soils.

___ Efficient mechanical methods for repairing soil damage caused by tractor traffic on saturated soils.

___ Equipment adaptations to reduce soil damage.

___ Additional retroactively effective fungicides and insecticides to allow applications to made only after know infection / insect attack has occurred versus relying on pre-emptive protective applications based on risk estimated from imperfect weather and pest forecast models.

___ Track driven tractors may have promise

1b Rapid fruit expansion

___ Calcium chloride sprays may be useful to increase the osmotic pressure out of the fruit.
___ Polymer sprays to seal the fruit.
___ Growth regulator treatments to reduce fruit cracking.

2c. Picking wet fruit increases bruising

___ Develop heated, padded, wet-grip picking gloves to reduce bruising of wet harvested fruit.

4. Drought

___ Fixed spray systems may be able to be adapted to assist with overhead irrigation. However, current fixed spray system designs are based on delivery through a short water pulse, not prolonged water supply needed for irrigation or frost protection. Perhaps the water supply lines could be serve multiple purposes.
___ Optimize extensive planting systems on drought-tolerant rootstocks with deeper root soil penetration.

5. Spring frost

___ Additional research is needed on foliar fruit sprays to increase freezing resistance.

6. Winter low temperatures

___ Does the combination of smaller shallow rooting rootstocks, vegetation-free herbicide strips, and trickle irrigation cause increased sensitivity to winter low temperature?

8. Warmer, longer growing seasons

___Applied research on biology, monitoring and management of new pest threats.

10. Increased frequency of temperatures over 90F

___ Include fruit sunburn resistance as criterion in cultivar breeding program evaluations.
___ What are the effects of overhead shade system and hail nets on fruit tree physiology under Northeast conditions?

11. Hail

___ Are hail cannons effective?

12. Access to capital

___ Compile grower data on frost, freeze, hail, flooding, drought and other weather events that have affected tree fruit production in recent years. Documenting damages could be useful for directing crop insurance, NRCS, research and Extension programs.

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